

QUALITY ANALYSIS OF MANGO FRUIT WITH FRUIT FLY INSECT BY NON-DESTRUCTIVE SOFT X-RAY METHOD

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ABSTRACT

Mango is known as “King of fruits” and it belongs to the genus *Mangifera* of the family Anacardiaceae. Mango has become naturalized and adapted throughout the tropics and subtropics. Defect of internal break down causes browning or blackening of arils, which gives a typical foul smell if unnoticed. The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), is one of the world's most destructive fruit pests, these fruit fly insect is commonly found in the mango fruit. These internal defects cannot be identified from external appearance, which is a serious threat to the mango processing industry as well as export resulting in rejections and quality reduction. X-ray inspection has a distinct advantage over other detection techniques, as it is non-destructive imaging of interior features of sample which detects internal defects. Soft X-ray emission spectroscopy is an experimental technique for determining the electronic structure of materials. A continuous soft X-ray system with a semi-conductor detector was used to detect the internal quality of the fruit. Thus the present study is one of soft x-ray technique to find the internal defects in mango. As to conquer and sustain the international market, there is a need for export of high quality products with no internal defects. The objectives of this study is to determine the internal defects in mango with fruit fly insect using soft x ray and to develop the algorithm for classification of defective mango from healthy one.

KEYWORDS: Soft X-Ray, Mango, Internal Quality Analysis, Image Processing

INTRODUCTION

India is the second largest producer for fruits and vegetables. Mango is known as “King of fruits” and it belongs to the genus *Mangifera* of the family Anacardiaceae. Mango has become naturalized and adapted throughout the tropics and subtropics. The fruit is also an important source of sustenance for insects, pests. As there is high demand for mango in world market, we choose mango for internal quality evaluation. Fruits and vegetables are increasing in popularity in the daily diets of the people of both developed and developing countries. For consumer awareness and export quality grade, grading and sorting of fruits is necessary. External quality such as size, shape, colour, tenderness, hardness is evaluated based on visual judgement and hand feel. This subjective grading and sorting causes a risk in processing and export. Product quality and quality evaluation methods are naturally important.

Several non-destructive techniques for quality evaluation have been developed based on the detection of various physical properties that correlate well with certain factors of a product. The quality of fruits and vegetables is based on

size, shape, colour, gloss, flavour, firmness, texture, taste and free from external as well as internal defects. Numerous techniques for evaluating the external quality factors are now available commercially. Internal quality factors such as maturity, sugar content, acidity, oil content, and internal defects, however, they are difficult to evaluate. Methods are needed to predict the internal quality of fruits and vegetables without destroying them. Recently, there has been an increasing interest in non-destructive methods of quality evaluation, and a considerable amount of effort has been made in that direction. Soft X-ray imaging is one among it. It is an established technique to detect strongly attenuating materials (gradual loss in intensity of any kind of flux through a medium) and has been applied to a number of inspection applications within the agricultural and food industries (Follett and Lower, 2000).

The basic aim of the work is to develop a system/ technique, which detects the presence of fruit fly inside the mango fruit in a non-destructive manner. This paper describes the initial stage in developing an automated non-destructive system for post harvest quality inspection. X-ray inspection has a distinct advantage over other detection techniques, as it is non-destructive imaging of interior features of sample which detects internal defects. This has become increasingly common in recent years in food industries of processed foods, packaged foods, canned foods, etc., due to increase in emphasis on food safety. There are two types of rays in x-ray which are known as, hard x-ray (energies above 5-10 keV & below 0.2-0.1 nm wavelength) and soft x-ray with low energy.

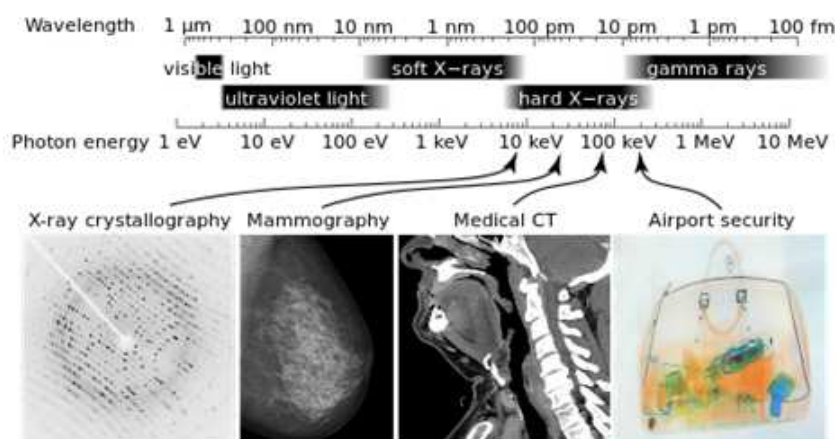


Figure 1: Electromagnetic Spectrum Radiation

The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), is one of the world's most destructive fruit pests. The species originated in sub-Saharan Africa. Its larvae feed and develop on many deciduous, subtropical, and tropical fruits and some vegetables. Some areas have had almost 100% infestation in stone fruits. Harvesting before complete maturity also is practiced in Mediterranean areas generally infested with this fruit fly. The mango tree suffers from numerous physiological, phytopathological and entomological problems.



Figure 2: Life Cycle of Fruit Fly Insect in Mango

Numerous techniques for evaluating the internal quality factors of fruits and vegetables are now available commercially. Several methods such as X-ray imaging, magnetic resonance imaging (MRI), Near Infrared Spectroscopy (NIRS), Ultrasound, Scanning Laser Vibrometry, etc can be implemented for non-destructive detection. After detailed comparison of these different techniques we came to conclusion that X-ray imaging is the appropriate and effective method for this application. X-ray is much more convenient and less expensive compared to MRI. Also it is one of the suitable techniques for detection of the internal defects since X-ray image gives information of whole fruit. After X-ray imaging is easily accessible, as this facility is available in the airport and in hospitals.

The line scanned x ray image of the sweet onions, showed that an overall classification accuracy of 90% can be achieved (Sahin et al, 2002b). X-ray imaging also shown promising results for detecting internal defects in grains. Wheat infested by weevils can be identified using the x-ray imaging (Karunakaran et al, 2003). X-ray image was used to measure the mass of wheat by calculating the total grey value of the image by Karunakaran et al (2004). With the help of soft x-ray insect infestation in guava by Jiang et al(2008), detection of weevil in mango by Thomas et al(1995)&Reyes et al (1999), insect infestation in peaches by Jiang et al (2008), translucency in pineapple by Haffet et al (2006) has been detected. Blasco et al(2009) invented an automatic sorting machine for pomegranate with the help of image analysis.

X-ray is a radiation and is a kind of electromagnetic wave wavelength is shorter than ultraviolet as well as microwaves. Use of X-ray radiation for food products has no problem in microbiological safety, and nutritional quality of irradiated food. X-ray imaging has been proven to be successful non-destructive methods ever to be applied in detecting diseases and defects in agricultural products. X-ray imaging requires interaction of X-ray photons with object, in this case, the mango. The infected mango shows light grey areas in the spongy tissue affected region. Uninfected mangoes show a uniform dark grey area. The reliability of X-ray imaging technique was proven when the mango is cut open.

The objectives of this study is to determine the possibilities of using soft X-ray to identify internal defects in mango and to develop an algorithm to measure percentage of infected part in the fruit.

MATERIALS AND METHODS

The samples were collected from IIHR, Hesaraghatta, Bangalore Karnataka. Selection was done on the basis of random sampling method where manually selection is done by external appearance. The fruits were artificially infested by mango fruit fly culture for our studies. The good fruit samples were kept in cage with mango fruit fly culture for overnight. The fruit fly enters the fruit. Then the insect starts growing in the fruit, the images were taken daily with the help of our Soft X-ray machine.

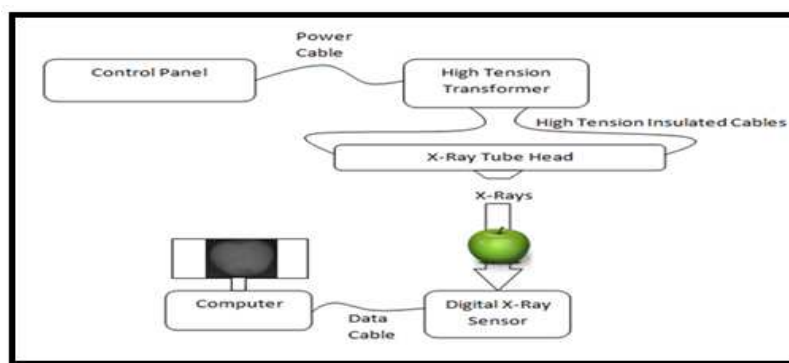


Figure 3: Circuit Diagram of Soft X-Ray Flow Pattern

X-ray images of Mangoes were acquired using soft x-ray machine in IICPT. The machine consists of 3 sub parts which are x-ray generator controlling unit, transformer and x-ray tube head. By using the generator control values of current (mA), voltage (kV) and time (sec) of exposure can be controlled. The value of mA and kV will be set accordingly for the object to be detected. The best combination will be used for capturing best quality image. Transformer generates high voltage required for x-ray generation up-to 160 kV and x-rays are generated in x-ray tube head.

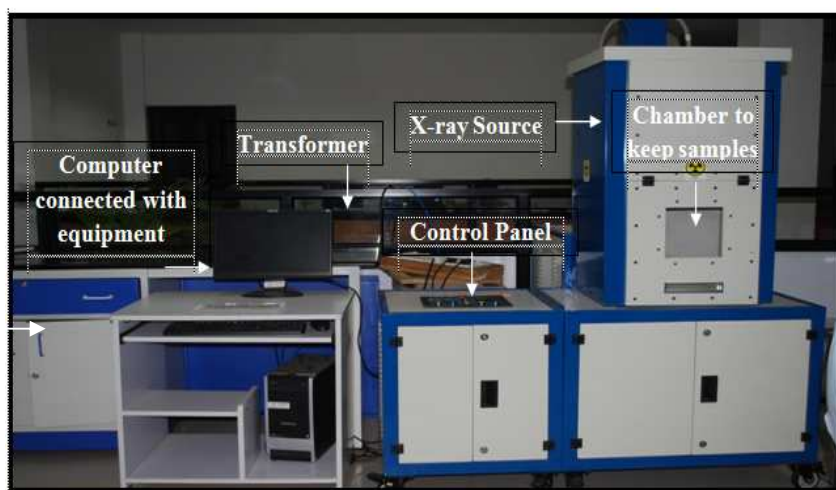


Figure 4: Soft X-Ray Equipment

Technical Details of the Soft X-ray Machine

X-Ray Generator

Anode voltage	0kVp – 160kVp Variable in steps of 1kV
Tube Head	Hermetically sealed oil bath
Tube Current	0mA – 5mA variable in steps of 0.1mA
Penetration	Suitable for all fruits & vegetables

Image Generating System

Detector type	Area Scan
Detector Area	185mm x 140mm
Image Resolution	2560 x 1920 pixels
Image Capture	Manual Trigger synchronized with the X-Ray Generator
Image Capture Settings	Using software interface installed in computer

Specification

Power supply	Stabilized 230V AC single phase 50 Hz
Power consumption	2.5 kV A maximum
Humidity	10 to 90% RH
Ambient Temperature	15 ⁰ C to 55 ⁰ C

Image

The Image quality depends on the values of gain, kV and mA, as well as exposure time. The best values of these are achieved by trial and error method which result in better quality image for further processing.

Processing of Obtained Image

The images were observed, the defected part of the fruit or the defect created by the fruit fly insect can be seen in

it, as it shows density difference. In the present study, we took X-ray images of Banganapalli variety of mango. Where the fruit fly disease is commonly found (Barcelon, 1999). Fruits with various internal structures were used to qualitatively evaluate the potential of using X-rays, to reveal internal injuries caused by pests or physical impingement. X-ray images taken from fruit infested by the Oriental fruit fly were digitized for further processing in order to investigate the distinct features of injuries caused by the pests in the soft parts of the fruit.

The images thus acquired by the machine are processed using image processing software (MATLAB 2010b). Algorithm was developed and colour map was used for the detection of the defective fruit.

The Image processing and the defect identification is processed by using the following steps in MATLAB algorithm;

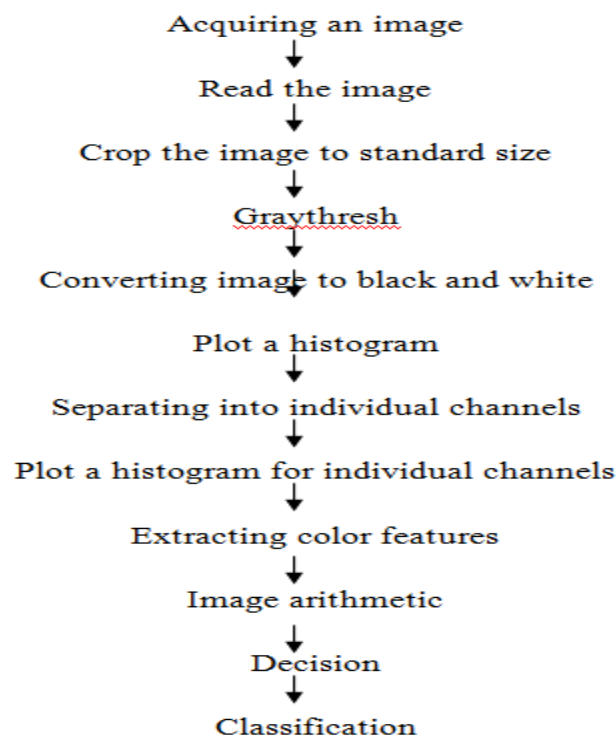


Figure 5: Process Flowchart in MATLAB for the Detection of Affected Area in a Mango Fruit

Process Flow chart

The flow of algorithm is as described below.

Original images converted to grayscale by eliminating the hue and saturation information while retaining the luminance. Converting it into Black and white image, no of black pixel value was counted which represents the non-defected parts. The function graythresh automatically computes an appropriate threshold to use to convert the grayscale image to binary. In thresholding the graythresh function uses Otsu's method, which chooses the threshold to minimize the intra-class variance of the black and white pixels with an intensity value lies in the range [0, 1]. Subtraction of the image from the original image to create a more uniform background. To provide better performance filling operation was made which traces the exterior boundaries of objects, as well as boundaries of holes inside the objects, in the binary image.

RESULTS AND DISCUSSIONS

Soft x-ray machine was used for capturing the images of fruit fly infected mango. Captured images are difficult to differentiate the defective and the good one. This soft x-ray images needs to be further processed as described above. The growth of fruit fly insect is observed using soft x-ray images. The image of fruit on its first day was taken and it is continued till it gets completely spoiled. The fruit quality goes decreasing as the growth of fruit fly inside affects the quality of a fruit. The fruit looks healthy in its external appearance but the soft x-ray image shows the affect of fruit fly inside. As the light source passes through fruit the damaged part of the will be having low density and light passes easily through it and grey colour appears in the image. The following figures show the change in internal changes in the fruit as the days of maturity of fruit fly increases it gets spoiled.

The following images show the difference between the Digital image and X-Ray image:

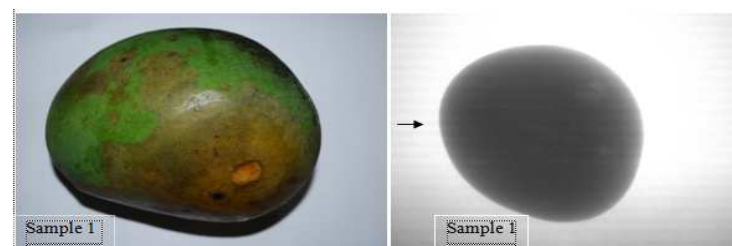


Figure 6 a

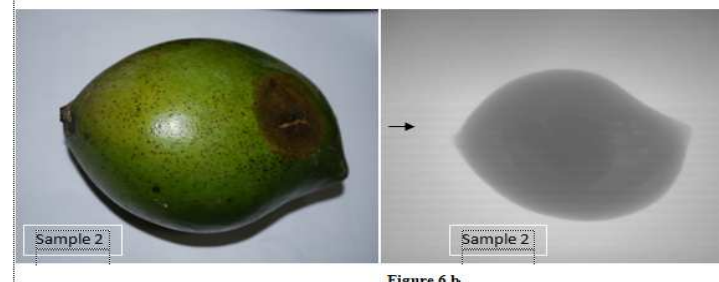


Figure 6 b



Figure 6 c

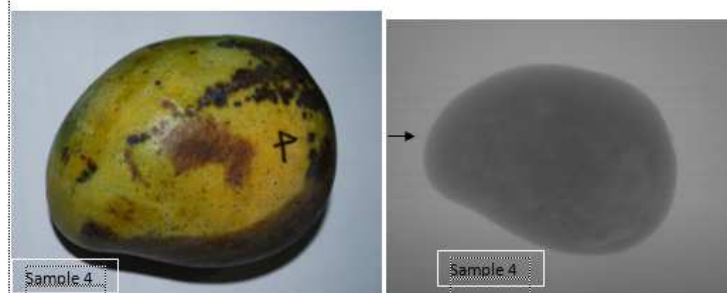


Figure 6 d

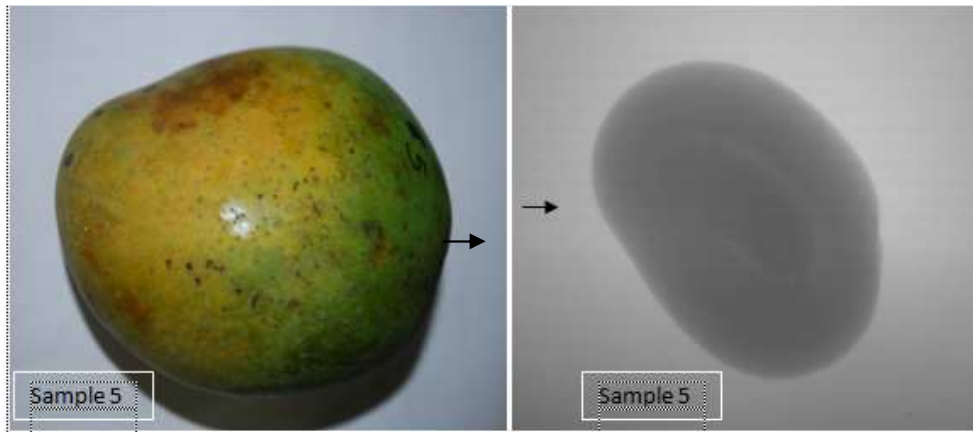


Figure 6 e



Figure 6 f

Figure 6: External and Soft X-ray images of mango Fruit sample with fruit fly insect on its following days

Figure a 1st day of Insect Growth

Figure b. 2nd day of insect growth

Figure c. 3rd day of insect growth

Figure d. 4th day of insect growth

Figure e. 5th day of insect growth

Figure f. Cut fruit sample after complete spoil of fruit

CONCLUSIONS

A real time X-ray system with a workstation for analysis captured and sends the images to a computer. The internal defects were differentiated based on X-ray absorption of images. The original x-ray images were not clear, it was not easy to detect the internal quality of the fruit. Computer algorithms were developed to differentiate between sound and internally defected mango fruits. These algorithms will detect the defects based either on absorption of X-ray and based on processed binary and RGB images. The algorithms were tested by providing samples of sound fruits and samples of fruits with natural and artificially induced defects. The integrity and effectiveness of the developed algorithm were tested based on several samples of sound and defected fruits. An obvious improvement in recognition capability of the designed system compared to that of the conventional method (visual inspection) was obtained. Thus the propose system and the algorithm is suitable for the improvement of the accuracy and the efficiency of the checking of the internal quality

of the fruits. In future this developed technology can be a promising computer vision system for detecting the mango fruit with internal and mechanical defects. This will make it easy for maintaining high grade export quality of mango.

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